Greene & Donoho

Duty Trial of a
Producer-Gas-Engine-Driven
26-Inch Centrifugal Pump

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DUTY TRIAL OF A PRODUCER-GAS-ENGINE-DRIVEN 26-INCH CENTRIFUGAL PUMP

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

WILLIAM BERTRAM GREENE EARL WILLOUGHBY DONOHO

ENTITLED DUTY TRIAL OF A PRODUCER-GAS-ENGINE-DRIVEN 26-INCH CENTRIFUGAL PUMP

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

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OUTLINE OF THESIS.

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DUTY TRIAL OF A PRODUCER GAS ENGINE DRIVEN 26" CENTRIFUGAL PUMP.

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DRIVEN 26" CENTRIFUGAL PUMP.

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INTRODUCTION.

This thesis consists of a commercial test made on a producer gas engine driven centrifugal pump at Pekin, Illinois. The plant is new and the tests herein discussed served in a measure as contract acceptance tests. The plant is owned by the Pekin and La Marge Drainage District, an organization of farmers formed for the purpose of erecting and operating a pump to drain the water from their low farm land into the Illinois river.

OBJECT OF TESTS.

The object of these tests, as indicated above is to determine the conformity of the actual efficiency of the pump with the manufacturer's guarantee.

NUMBER OF TESTS.

On March 25 and 26 tests were made on the complete plant, each test lasting about eight hours. During the first test the engine stopped once and several times it slowed down, and accordingly the second test was run in hopes of getting better operation of the engine. Between the two tests the engine main bearings and reciprocating parts were carefully examined and adjusted. A one hour test for the mechanical efficiency

of the engine was run on March 27 to permit an analysis of the performance of the component parts of the installation.

DESCRIPTION OF PLANT.

PUMP.

The pump tested was a Lawrence Double Suction 26" Centrifugal Pump, run at 210 R. P. M. It was driven thru a continuous rope drive of 1 1/4" rope of nine turns as shown on drawing, page . The pump was located about two feet above the suction level in a small "lean to" which adjoined the engine house. The engine house floor was seven feet above the pump.

ENGINE.

A vertical three cylinder four cycle 14" x 15" Webber engine rated at 125 H.P. was used to run the pump. Ignition was taken care of by a small magneto; governing was done by means of throttling the mixture.

PRODUCER.

Two producers had been installed with one scrubber between them; only one of the producers was needed for operation and the same one was used continuously. They were Webber Suction Producers rated at 125 H.P.

ACCESSARIES.

A jack shaft over head could either be connected to the large engine or it could be run by a small gasoline engine. To this were connected a suction fan for starting the producer, a small rotary pump for circulating the cooling water and a

small generator for lighting the plant. An air compressor was connected directly to the gasoline engine and pumped air into a tank; by means of this compressed air the large engine was started.

TESTS.

The following observations were made at ten minute intervals thruout the test with exception of "General Data" which was taken every hour.

1. DUTY TRIALS.

General Data.

1. Barometer reading.
2. External air temperature.
3. Engine room temperature.

Engine performance.

4. Temperature of jacket water, initial.
5. Temperature of jacket water final.
6. Temperature of gas to engine.
7. Temperature of exhaust.
8. Weight of jacket water per minute.
9. Weight of coal to producer.
10. Weight of ash.
11. R. P. M. of Engine.
12. E. P. M. of engine.
13. Indicator diagram, Cylinder No. 1.
14. Indicator diagram, Cylinder No. 2.
15. Indicator diagram, Cylinder No. 3.

Pump Performance.

16. Temperature of Suction Water.

17. Suction head.

18. Delivery head.

19. Velocity head in suction pipe, Pitot tube reading.

20. Velocity head in discharge pipe, Pitot tube reading.

21. R. P. M. of pump.

2. MECHANICAL EFFICIENCY TEST.

General Data.

1. Barometer reading.

2. External air temperature.

3. Engine room temperature.

Engine Performance.

4. Temperature of gas to engine.

5. Temperature of exhaust gas.

6. Temperature of jacket water, initial.

7. Temperature of jacket water, final.

8. Indicator diagram, Cylinder No. 1.

9. Indicator diagram, Cylinder No. 2.

10. Indicator diagram, Cylinder No. 3.

11. R. P. M. of engine.

12. E. P. M. of engine.

13. Net Weight of brake on scales.

METHOD.

In order to determine the mechanical efficiency of

the pump the combined efficiency of the engine and pump had first to be obtained by taking the ratio of the water horse power to the indicated horse power. This ratio divided by the mechanical efficiency of the engine gives the pump efficiency including transmission.

TO GET PLANT EFFICIENCY.

Samples of coal and ash were taken for testing and all coal put into hopper and all ash from the grates was weighed for the purpose of getting the thermal efficiency of the plant. The thermal efficiency is the ratio of the delivered horse-power to the horse power equivalent to the B. T. U.delivered in the coal to the producer, correction being made for heat in refuse.

TEMPERATURES.

All temperatures of gas, water and air were taken merely for purposes of general information as a heat balance or analysis was impossible in the absence of a gas analysis.

JACKET WATER.

The weight of jacket water per minute was obtained by timing the flow into a bucket with a stop watch and weighing the same. This did not enter into the final calculations for the reasons already given of the impractibility of a heat balance.

INDICATOR CARDS.

Indicator springs were calibrated after the test was made. The reducing motion consisted of a long cord passing across the top of the engine where the indicators were located,

and guided by pulleys down to the end of the shaft, where there was an arrangement that enabled an operator to hook the cord onto anyone of three cranks which worked in phase with the eif- ferent cylinders. The accompanying sketch, page , will better show the arrangement.

R.P.M. OF ENGINE.

This was obtained by means of a tachometer which had been calibrated with an ordinary speed counter.

R.P.M. OF PUMP.

This was obtained by multiplying the engine R.P.M. by the velocity ratio of the two pulleys.

VELOCITY HEAD.

Calibrated Pitot tubes were placed in the discharge and in the suction pipe and were read simultaneously. The reading of the one in discharge pipe was accepted as standard as it was placed in a straight section of pipe and the other had necessarily been placed near a bend.

SUCTION HEAD.

This was obtained by means of a vacuum gage.

DISCHARGE HEAD.

This was measured with a mercury column connected by tubing to the discharge end of the pump.

RESULTS.

From the above observations and from the coal and ash analyses the following results were calculated.

Item.	Trial No. 1. Mar. 25, '08	Trial No. 2. Mar. 26, '08
1. Duration of trial, hours,	7.4	7.58
2. Atmospheric pressure, lbs. per sq. in. (Reading No. 1 x .493	14.0	14.15
3. Average external air temperature (From reading No. 2)	66.5°F.	65.2°F.
4. Average engine room temperature. (From reading No.3)	70.6°F.	70.1°F.
5. Average temperature of gas to Engine. (From reading No. 6)	68.7°F.	72.3°F.
6. Average temperature exhaust gases. (From Reading No.7)	208.4°F.	254.6°F.
7. Average initial temperature of jacket water. (From reading No. 4)	54.0°F.	64.3°F.
8. Average final temperature of jacket water (From reading No. 5)	100.5°F.	141.8°F.
9. Average temperature difference. ("Item 8" - "Item 7")	46.5°F.	77.5°F.

		Trial No. 1.	Trial No. 2.
10.	Average R.P.M. of engine (From Reading No. 11)	284	295
11.	Average Explosion per minute. ("Item 10" ÷ 2)	142	147.5
12.	I.H.P. cylinder No. 1. (.00584 x M.E.P. x "Item 11")	18.1	27
13.	I.H.P. cylinder No. 2.	17.5	21.9
14.	I.H.P. cylinder No. 3.	25.6	24.1
15.	Total I.H.P. for engine. ("Item 12" "Item 13" "Item 14")	61.2	73
16.	Average temperatures of suction water, T. (From reading No. 16)	51.8°	59.4°
17.	Average velocity of flow in suction pipe in ft. per sec. V' (V' = 2 g h ; h, velocity head in pitot tube, in feet of water from reading No. 19)	8.04	7.96
18.	Average R.P.M. of pump. ("Item 10" x 54/40)	210	219
19.	Average velocity of flow in discharge pipe in ft. per sec, V. V = .975 2 g h)	7.53	7.56

		Trial No. 1.	Trial No. 2.
20.	Average celocity. (("Item 17" "Item 19") ÷ 2)	8.09	7.76
21.	Water pumped, cubic feet per second. Q. (Q = V x A, A = area discharge pipe)	27.7	27.8
22.	Water pumped, gallons per minute, G.; (G = t0 x Q x D, D = gallons per cubic foot at temperature T, "Item 16")	12,400	12,450
23.	Water pumped, pounds per second. ("Item 19" x weight per cubic foot at temperature, T)	1732	1739
24.	Total gage head, feet. (Average reading No. 17 and No. 18)	9.06	8.43
25.	Total level head, feet. (Measurement)	8.08	8.08
26.	Water horse power. ("Item 23" x (Reading 17 Reading 18)) all divided by 550	28.6	27.61
27.	Effective horse power. $\frac{\text{"Item 27" x "Item 25"}}{550}$	26.4	26.5
28.	Capacity of pump, gallons per 24 hours. "Item 22" x 60 x 24.	17840000	17910000
29.	Total coal burned per hour as fired. Reading No.9 ÷ Item 1.	117.2	93.2

		Trial No. 1.	Trial No. 2.
30.	Total coal burned, lbs per I.H.P. hour. "Item 29 ÷ "Item 15"	1.92	1.275
31.	Total coal burned, lbs. per B.H.P. hr. "Item 30" ÷ .786, Mech. eff.	2.44	1.623
32.	Total coal burned, lbs. per I.H.P. hour. "Item 29"÷ "Item 26"	4.1	3.39
33.	Total coal burned, lbs. per effective horse power hour. "Item 29" ÷ "Item 27"	4.44	3.52
34.	Total ash and refuse per hour,	35.20	21.25
35.	Coal analysis.		
	Moisture,	2.15%	1.43%
	Ash	15.83	15.25
	Sulphur	.94	.91
	Hydrogen.	2.80	2.84
	Carbon	75.68	76.76
	Nitrogen	.85	.85
	Oxygen	1.75	1.96
	B.T.U. per lb. of coal as fired (Parr calorimeter)	12,330	12,569
36.	Ash analysis.		
	Moisture	1.10%	.64%
	Volitile matter	45.64	42.54

	Trial No. 1.	Trial No. 2.
36. (Continued)		
Fixed carbon	53.26	56.82
Ash		
B.T.U. (calculated)	6861	6417
37. B.T.U. per hour supplied to the producer. "Item 29 x "Item 35"	1,445,000	1,171,500
38. B.T.U. per hour supplied to producer and rejected in refuse. "Item 34" x "Item 36"	241,500	136,350
39. Net B.T.U. evolved per hour in producer. "Item 37" - "Item 38"	1,203,500	1,035,150
40. B.T.U. per I.H.P. hr. "Item 39" ÷ "Item 15"	23,600	16,045
41. B.T.U. per B.H.P. hr. "Item 39" ÷ (.786, Mech. eff.x I.H.P.)	30,040	20,410
42. B.T.U. per W.H.P. hr. "Item 39" ÷ "Item 26"	48,850	42,820
43. B.T.U. per effective H.P. hr. "Item 39" ÷ "Item 27"	54,800	45,400
44. Pump Duty. (Foot-lbs. of work done per 1,000,000 B.T.U. supplied bases upon coal as fired and pump horse-power.	39,220,000	44,750,000

		Trial No. 1.	Trial No. 2.
45.	Overall pumping efficiency. (Ratio of heat equivalent of W.H.P. to "Item 39")		
46.	Overall plant efficiency. (Ratio of heat equivalent of effective horse power to "Item 39)	4.66%	5.75%
47.	Potential efficiency of Producer, transmission, engine and pump. "Item 39" and W.H.P.	6.05%	6.72%
48.	Efficiency ratio, Mech. eff. (B.H.P. ÷ I.H.P.)	78.6%	78.6%
49.	Efficiency ratio. (W.H.P. ÷ I.H.P)	46.7%	36.6%
50.	Efficiency ratio. (Effective horse power ÷ I.H.P.)	43.3%	36.3%

SUMMARY OF RESULTS.

The following table shows significant results as taken from the previous table, compared with normal results which should be expected.

	Item.	Trial No.1.	Trial No.2.	Normal.
1.	Duration of trial, hrs.	7.8	7.28	
15.	Total average I.H.P.	61.2	73	147
48.	Mechanical efficiency of engine.	78.6%	78.6%	85%
	Estimated B.H.P.	48.1	57.3	125
17.	Velocity in discharge pipe, feet per second.	8.64	7.96	10
22.	Water pumped, gallons per minute.	12,400	12,450	16,650
26.	W.H.P.	28.6	26.61	35.4
27.	Effective horse power	26.4	26.50	34
28.	Capacity of pump, gallons per 24 hrs.	17,8740,000	17,910,000	24000000
31.	Coal burned per B.H.P;	2.44	1.62	1.25
35.	B.T.U. per pound of coal.	12,330	12,569	12,500
44.	Pump Duty.	39,2200,000	46,580,000	
49.	Efficiency ratio, W.H.P. ÷ I.H.P.	46.7%	36.6%	80%
50.	Efficiency ratio. Effective H.P. ÷ I.H.P.	43.3%	36.37%	75%

CONCLUSIONS.

Owing to rather unsatisfactory performance of the engine and producer during test, the results as a whole probably err as high as 5%. Still with the results obtained and the record of performance the following conclusions may be drawn.

The high percentage of unburned carbon in the ash and the large amount of ash and refuse rejected from the producer are a result of too frequent cleaning and poking of the fire and show inefficient firing. The behavior of the engine is accounted for by a poor quality of gas irregularly supplied. The amount of coal burned per B.H.P. hour, 1.62 lb., is much too high.

The load on the engine is less than half of normal rating thus decreasing to a great extent both the thermal and mechanical efficiency. During the brake test for the determination of mechanical efficiency of the engine the indicator on Cylinder No. 2 was out of commission and the total I.H.P. had to be estimated from the previous performance. The mechanical efficiency of the engine as obtained was 78.6%.

The pump was not worked to its full capacity due to the fact that the screen over the end of the intake pipe shut off one fourth of the opening; this also often became clogged; reducing still further the effective area. This condition impairs the efficiency to a very considerable extent and at normal load reduces the capacity of the pump. The velocity of water

in the pipe 7.85 feet per second was lower than normal capacity demands.

The column of normal results to be expected, shown under "Summary of Results" shows a wide variation from those actually obtained.

DRIVEN 26" CENT
E DRAINAGE DIST
IN ILLINOIS

[illegible]	Vel. Head in Feet Suction 22	Disc 22	Avge 23
64.1	1.13	1.00	1.065
67.4	1.13	.96	1.045
66.3	1.13	.93	1.03
65.5	.905	.96	.932
62.8	.905	.98	.942
62.5	.905		
55.0	1.13		
57.5	.905		
56.0			
62.0	1.13		
68.5		.71	
67.0		.85	
68.6			
68.0		.83	
65.0		.96	
		.98	
61.4		.96	
59.5		1.00	
54.7		1.02	
41.4		.67	
55.6		.79	
51.7		.77	
48.4		.77	
44.1		.54	
60.0	1.13	.67	.90
60.1	1.13	.67	.90
60.3	1.35	1.04	1.195

3:46 — 11:10 P.M.

7 hours. 24 min.

March 25, '08

TEMP

in Feet

Mechanical Efficiency of Pump

28.4

Clear & windy

P.M.																																				
3:46	70.0	72	55	102	47	70	180	54.0	82"	300	222	150	20.4	22.0	31.1	24.5	17.9	18.9	27.3	64.1	1.13	1.00	1.065	4.52	5.10	9.62	8.08	27.9	12,530	753,000	18,080,000	30.6	25.6	.84	.610	Ratio Engine Pulley Dia. to Pump
3 55	69.5	72	55	101	46	68	207	54.0		300	222	150	23.2	19.6	34.0	25.6	20.4	17.2	29.8	67.4	1.13	.96	1.045	4.52	4.88	9.40	8.08	27.3	12,280	736,000	17,700,000	29.2	25.1	.86	.552	Pulley Dia. 49/54
4:00			55	101	46	68	222	54.0		300	222	150	22.7	19.0	33.9	25.2	20.0	16.6	29.7	66.3	1.13	.93	1.03	4.52	4.88	9.40	8.08	27.1	12,130	730,000	17,500,000	28.8	24.8	.86	.556	
10	70.0	72	55	104	49	66	198	54.0		292	216	146	23.6	19.4	33.7	25.6	20.2	16.5	28.8	65.5	.905	.96	.932	4.30	4.75	9.05	8.08	27.4	12,280	737,000	17,700,000	28.0	25.0	.894	.566	
20			50	101	51	70	190	54.0		288	213	144	23.6	20.5	30.6	24.9	20.0	17.2	25.6	62.8	.905	.98	.942	3.96	4.75	8.71	8.08	28.8	12,920	776,000	18,600,000	28.5	26.4	.922	.584	
30	69.0	72	55	106	51	70	195	54.0		284	210	142	23.6	19.6	32.3	25.2	19.6	16.2	26.7	62.5	.905			3.96	4.75	8.71	8.08							.922		
40			55	98	43	71	229	54.0	101.5	262	194	131	21.6	20.5	29.0	23.9	16.5	16.3	22.2	55.0	1.13			4.20	4.75	8.95	8.08							.903		
50			55	97	42	71	222	54.0	86.	280	207	140	21.1	19.8	29.4	23.4	17.3	16.2	24.0	57.5	.905			3.96	4.75	8.71	8.08							.927		
5:00	69.5	72.5	55	96	41	70	214	54.0		270	200	135	21.2	19.0	33.9	24.7	16.9	15.0	24.1	56.0				3.68	4.71	8.39	8.08							.965		
10			54	99	45	71	201	54.0		292	216	146	23.2	19.0	30.5	24.2	19.8	16.2	26.0	62.0	1.13			3.96	4.65	8.61	8.08							.939		
20			55	106	51	70	194	54.0		292	216	146	25.3	22.0	33.0	26.7	21.6	18.7	28.2	68.5		.71		4.40	4.65	9.05	8.08	23.5	10,550	635,000	15,200,000	24.0	21.5	.899	.447	
30			54	109	55	70	194	54.0		295	218	147.5	25.6	19.7	32.4	25.9	22.1	16.9	28.0	67.0		.85		4.40	4.65	9.05	8.08	25.8	11,550	694,000	16,600,000	26.4	23.6	.899	.576	
40			54	110	56	71	236	54.0		298	221	149	23.9	21.5	33.4	26.3	20.8	18.7	29.1	68.6				4.53	4.65	9.18	8.08							.88		
50			54	111	57	70	250	53.5		300	222	150	26.0	19.8	31.8	25.9	22.8	17.3	27.9	68.0		.83		4.53	4.65	9.18	8.08	25.5	11,450	688,000	16,500,000	26.6	23.4	.88	.502	
6:00	66.5	71	55	111	56	70	250	53.4		292	216	146	24.4	20.3	31.4	25.2	20.9	17.3	26.8	65.0		.96		4.53	4.52	9.05	8.08	27.3	12,280	738,000	17,700,000	28.0	25.0	.894	.559	
.10			54	107	53	70	270	53.0		290	215	145	24.4	20.1	31.4	25.3	20.7	17.0				.98		4.53	4.65	9.18	8.08	27.7	12,400	745,000	17,900,000	28.7	25.3	.88		
20			54	112	58	70	280	53.0		286	212	143	22.7	20.4	30.4	24.5	19.0	17.0	25.4	61.4		.96		4.53	4.52	9.05	8.08	27.3	12,280	738,000	17,700,000	28.0	25.0	.894	.583	Generator thrown in.
30			54	105	51	71	284	53.0		284	210	142	22.0	19.6	30.2	23.9	18.3	16.2	26.0	59.5		1.00		4.30	4.58	8.88	8.08	27.9	12,530	753,000	18,080,000	28.2	25.6	.908	.605	
40				103	49	70	180	53.0		280	207	140	20.0	18.9			16.4	15.4	22.9	54.7		1.02		4.06	4.56	8.62	8.08	28.2	12,670	760,000	18,150,000	27.6	25.9	.938	.645	
53				99	45	70	160	53.0		260	193	130	19.6	17.0	28.0	21.5	14.9	12.9	13.6	41.4		.67		3.28	4.40	7.68	8.08	22.8	10,230	615,000	14,720,000	19.9	20.9	1.05	.605	
7:00	66.0	70		96	42	70	168	52.9	85.5	270	200	135	19.6	19.3	31.5	23.5	15.5	15.2	24.9	55.6		.79		3.50	4.64	8.14	8.08	24.8	11,140	670,000	16,080,000	22.9	22.7	.994	.526	
10			54	95	41	70	172	52.9		268	199	134	19.4	17.3	29.7	22.1	15.2	13.5	23.0	51.7		.77		4.18	4.52	8.70	8.08	24.5	11,000	660,000	15,850,000	24.2	22.5	.93	.599	
20				98	44	70	168	52.9		260	193	130	16.0	18.8	29.0	21.3	12.2	14.2	22.0	48.4		.77		3.40	4.41	7.81	8.08	24.5	11,000	660,000	15,850,000	21.9	22.0	1.03	.579	
30				96	42	70	164	52.9		248	184	124	16.0	19.1	25.4	20.2	11.6	14.2	18.3	44.1		.54		3.28	4.41	7.69	8.08	20.6	9,230	555,000	13,300,000	17.9	18.8	1.05	.520	Engine stopped 7:37
8:30		68	54	82	28	70	180	53.0		292	216	146	20.7	20.3	29.2	23.4	17.7	17.3	26.0	60.0	1.13	.67	.90	4.06			8.08	22.8	10,230	615,000	14,750,000		20.9			Intake sucked air till
40				84	30	68	198	53.0		284	210	142	20.0	23.8	28.8	24.2	16.7	19.6	23.8	60.1	1.13	.67	.90	4.06			8.08	22.8	10,230	615,000	14,750,000		20.9			9:00 P.M.
50				86	32	68	195	52.9		280	207	140	22.0	20.9	30.7	24.5	18.1	17.1	25.1	60.3	1.35	1.04	1.195	4.06	5.75	9.81	8.08	27.3	12,280	736,000	17,700,000	30.4	25.0	.825	695	
9:00	63.0	68		87	33	67	204	52.9	120.	284	210	142	17.9	23.3	31.5	24.2	14.9	19.3	26.0	60.2	1.33	1.03	1.180	4.18	5.36	9.54	8.08	28.3	12,750	766,000	18,380,000	30.7	26.0	.848	652	
10				89	35	68	222	52.9		292	216	146	17.9	22.5	31.6	24.0	15.3	19.2	27.0	61.5	1.33	.96	1.145	4.30	5.10	9.40	8.08	27.3	12,250	736,000	17,700,000	29.1	25.0	.86	605	
20				88	34	68	216	52.9		290	215	145	17.9	21.1	31.8	23.6	15.2	17.8	27.0	60.0	1.24	1.00	1.120	4.40	5.10	9.50	8.08	27.9	12,540	754,000	18,070,000	31.6	25.6	.85	.675	
30			53	88	35	68	210	51.6		288	213	144	22.0	21.1	32.0	25.0	18.5	17.7	26.9	63.1	1.18	1.04	1.110	4.45	5.20	9.65	8.08	28.5	12,800	768,000	18,950,000	31.4	26.1	1.21	.625	
40				88	35	66	219	52.3		284	210	142	22.0	23.8	27.1	24.3	18.3	19.7	22.4	60.4	1.13	1.04	1.085	4.52	5.30	9.82	8.08	28.5	12,800	768,000	18,960,000	31.7	26.1	.823	.672	
50				87	34	66	207	52.3		284	210	142	22.4	22.7	34.6	26.5	18.5	18.8	28.6	65.9	1.35	1.04	1.195	4.52	5.20	9.72	8.08	28.5	12,800	768,000	18,950,000	31.4	26.1	.831	.612	
10:00	60.5	68	53	89	36	66	214	52.3	154.	296	219	148	21.2	23.5	34.0	26.2	18.3	20.3	29.4	68.0	1.19	1.04	1.115	4.63	5.20	9.83	8.08	28.5	12,800	768,000	18,950,000	31.7	26.1	.822	.596	
10				89	36	67	202	52.2		290	215	145	21.2	22.5	32.1	25.2	17.9	19.0	27.2	64.1	1.30	1.04	1.170	4.63	5.25	9.88	8.08	28.5	12,800	768,000	18,950,000	31.8	26.1	.82	.637	
20				89	36	66	202	52.2		288	213	144	22.8	23.2	32.6	26.2	19.1	19.5	27.4	66.0	1.24	1.04	1.140	4.52	5.30	9.82	8.08	28.5	12,800	768,000	18,950,000	31.7	26.1	.823	.616	
30			53	88	35	67	208	52.2		284	210	142	22.8	24.1	34.6	27.1	18.9	19.9	28.6	67.4	1.24	1.08	1.160	4.52	5.20	9.72	8.08	29.1	13,052	784,000	18,800,000	32.3	26.6	.824	.615	
40				88	35	67	212	52.2	116.5	284	210	142	21.2	23.3	33.0	25.8	17.8	19.3	27.3	64.4	1.30	1.04	1.170	4.52	5.15	9.67	8.08	28.5	12,800	768,000	18,950,000	31.1	26.1	.838	.610	
50				89	36	67	210	52.2		284	210	142	20.7	24.3	30.7	25.2	17.2	20.0	25.4	62.6	1.35	1.02	1.185	4.52	5.15	9.67	8.08	28.2	12,680	760,000	18,250,000	32.0	26.8	.836	.654	
11:00	61.0	68	53	88	35	66	210	52.2	142.5	280	207	140	21.6	23.2	26.5	23.8	17.7	19.0	20.8	57.5	1.07	1.02	1.045	4.07	5.10	9.17	8.08	28.2	12,680	760,000	18,250,000	30.2	26.8	.881	.672	
10				89	36	66	210	52.2	119.0	295	218	147.5	26.7	23.8	28.6	26.4	23.1	21.3	24.7	69.1	1.13	1.06	1.095	4.52	5.15	9.67	8.08	28.7	12,900	775,000	18,600,000	31.4	26.3	.836	.580	
Total	665.0	776.5	1298	2410	111.6	2818	8547	2125.1	1007.0	11670	8640	5835	890.1	859.6	1238.2	985.1	743.7	715.6	1022.0	2443.6	30.26	31.51	22.980	173.51	190.29	353.68		9690	424642	26,020,000	625,060,000	942.9	924.2	34.091	19000	
Avge	66.5	70.6	54.0	100.5	4.65	68.7	208.4	51.8	111.89	284	211	142	21.7	20.96	30.95	24.62	18.1	17.5	25.6	61.2	1.16	.928	1.044	4.23	4.83	9.06	8.08	27.7	12,400	744,000	17,840,000	28.6	26.4	.885	.594	

1 2

2.40 10.15 P.M.

7 hrs. 35 min.

March 26 '08

MECH. EFF. of PUMP 28.56

CLEAR + WINDY

TEMP.

GAS

P.M.																																				
2.40	69	69.5	66	127	61	72	302	60.9	60.9	300	222	150	37.5	28.6	21.3	29.1	32.8	24.2	17.7	77.4	.79	.79	.79	4.87		(8.84)	8.083	25	11.150	670.000	16100000	24.8	22.7	.915	.422	
.50			65	133	68	72	273	60.9	60.9	302	223	151	31.7	23.0	32.8	29.1	28.0	19.3	28.0	75.3	.80	.79	.795	4.87		(8.84)	8.083	25	11.150	670.000	16100000	24.8	22.7	.915	.434	
3.00	69	70	65	137	72	72	257	60.9	60.9	300	222	150	33.7	23.2			29.5	19.4			.825	.79	.805	4.87		(8.84)	8.083	25	11.150	670000	16100000	24.8	22.7	.915		
3.08			66	137.5	71.5	72	264	60.9	60.9	300	222	150	36.0	29.7			32.5	23.5			.800	.875	.837	4.87	3.97	8.84	8.083	25.75	11,710	705000	16900000	26.1	23.9	.915		
.16			65	137.5	72.5	73	256	60.9	60.9	300	222	150	34.1	22.9	29.6	28.8	29.9	19.1	25.0	74.0	.800	.85	.815	4.87	3.97	8.84	8.083	25.4	11580	695000	16700000	25.8	23.6	.915	.460	
.24			65	135	70	73	350	60.9	60.9	298	221	149	33.0	25.0			28.7	20.8			.79	.895	.8425	4.87	3.97	8.84	8.083	24.8	11300	678000	16300000	25.1	23.1	.920		
.32	68	70	59	127	68	72	338	60.9	60.9	300	222	150	29.1	27.0	34.4	30.1	25.4	22.7	29.3	77.4	.79	.855	.8175	4.87	3.97	8.84	8.083	26.1	11590	695000	16710000	25.7	23.6	.920	.438	
.40			65	133	68	73	304	60.9	60.9	298	221	149	34.4	21.0	34.6	30.0	29.9	17.3	29.1	76.3	.825	.855	.84	4.87	3.97	8.84	8.083	26.1	11590	695000	16710000	25.7	23.6	.920	.474	
.48			65.5	131.5	66	73	276	60.9	60.9	276	207	138	33.4	26.2	29.4	29.6	26.9	20.1	22.9	69.9	.675			5.10	3.85	8.95	8.083									
.56			66	129	63	73	280	60.9	60.9	304	223	152	30.8	26.4	32.9	30.0	27.2	22.4	28.2	77.8	.78	.75	.765	5.00	3.97	8.97	8.083	23.8	10860	652000	15650000	24.6	22.1	.908	.417	
4.04	67		66	131	65	73	276	60.9	60.9	298	221	149	35.2	28.3	24.4	30.0	36.0	23.7	22.1	81.8	.715	.73	.7225	5.00	3.97	8.97	8.083	23.48	10700	643000	15420000	24.2	21.8	.900	.380	
.12			66	139	73	72	274	60.9	60.6	300	222	150	29.3	27.3	31.0	29.9	25.7	23.0	26.2	74.9	.79	.79	.790	4.87	3.97	8.84	8.083	25.00	11150	670000	16100000	24.9	22.7	.912	.444	
.20			66	141	75	72	268	60.6	60.3	286	212	143	33.0	24.3	33.6	30.4	25.5	19.4	27.1	72.0	.75	.79	.770	4.53	3.85	8.38	8.083	25.00	11150	670000	16100000	23.6	22.7	.962	.432	
.28			65	140	75	73	266	60.3	59	290	213	145	33.9	27.3	31.0	30.7	28.6	22.3	25.4	76.3	.92	.96	.740	4.76	3.4	8.16	8.083	27.40	12500	750000	17650000	25.7	25.5	.990	.444	
.36			64.5	138.5	74	73	252	59.2	65	276	204	138	31.3	24.7	31.2	29.1	25.3	19.0	24.3	68.6	.71	.875	.797	3.96	3.74	7.70	8.083	25.75	11710	705000	16900000	22.8	23.9	1.045	.438	
.44			65	136.5	71.5	72	258	59.0	60	296	219	148	35.0	27.0	32.0	31.3	32.0	19.8	20.8	72.6	.79	1.06	.930	4.82	3.97	8.79	8.083	28.4	12930	776000	18670000	28.7	26.4	.920	.432	
.52			64.5	136	71.5	72	259	59.0	—	284	210	142	36.8	28.1	30.4	31.8	30.0	22.4	24.3	76.7	.675	1.04	.857	4.53		(8.53)	8.083	28.5	12700	753000	18400000	27.3	25.9	.950	.468	
5.00	65	72	65	134.5	69.5	73	246	59.0	—	290	215	145	30.2	25.5	29.4	28.3	25.6	20.9	24.1	70.6	1.04	.98	1.010	4.51		(8.61)	8.083	27.7	12400	745000	17880000	26.9	25.3	.940	.506	
.08			61	129	68	72	250	58.9	—	282	209	141	29.0	26.2	29.2	28.1	23.9	20.7	23.2	67.8	1.04	.98	1.010	4.13		(8.80)	8.083	27.7	12400	745000	17880000	27.5	25.3	.920	.534	
.16			63	130	67	71	244	58.8	61.5	300	222	150	29.4	28.5	27.3	28.4	25.7	24.1	22.3	72.1	1.21	1.12	1.160	4.86	4.19	9.05	8.083	29.7	13280	796000	19150000	33.3	27.1	.895	.595	
.24			65	137	72	72	249	58.8	57	288	213	144	32.3	27.0	30.2	29.8	27.1	21.9	24.6	73.6		1.06		4.42	3.74	8.16	8.083	28.4	12930	776000	18630000	27.7	26.4	.955	.495	
.32			66	138.5	72.5	73	244	58.8	—	294	218	147	30.4	25.9	29.9	28.7	28.0	21.5	24.8	74.3	1.27	1.12	1.190	4.76	3.97	8.73	8.083	29.7	13280	798000	19150000	29.2	27.1	.927	.517	
.40			66	141.5	75.5	72	265	58.8	—	298	221	149	30.8	26.4	31.4	29.5	26.8	22.6	26.5	75.9	1.27	1.14	1.205	4.86	3.85	8.71	8.083	30.0	13400	805000	19310000	29.5	27.3	.927	.512	
.50			66.5	144	77.5	72	257	58.8	—	304	223	152	32.4	26.6	29.4	29.1	28.7	22.0	25.1	75.8	1.38	1.17	1.275	4.86	4.08	8.96	8.083	30.3	13520	813000	19500000	30.6	27.6	.902	.532	
.58	63.5		66.5	148	81.5	70	262	58.8	54	302	223	151									1.32	1.14	1.230	4.99	3.85	8.84	8.083	30.0	13400	805000	19310000	29.8	27.7	.930		
6.04	60.	70	66.5	149	82.5	71	248	58.8	—	300	222	150	31.8	27.7	32.4	30.6	27.8	23.4	27.4	78.6	1.27	1.12	1.195	4.93	3.85	8.79	8.083	29.7	13280	797000	19150000	29.3	27.1	.925	.479	
.12			66.5	148	81.5	71	248	58.8	—	294	218	147	37.6	29.0	29.4	32.0	32.4	24.0	24.4	80.8	1.27	1.14	1.205	4.99	3.85	8.84	8.083	30.0	13400	805000	19310000	29.9	27.3	.916	.487	
.20			66	139	73	70	236	58.8	—	282	209	141	31.2	26.5	29.6	29.1	26.8	24.7	24.4	72.9	1.15	1.16	1.155	4.61	3.74	8.25	8.083	28.8	12930	776000	18630000	27.8	26.4	.985	.502	
.28			65.5	140	74.5	69	246	58.8	49.5	300	222	150	32.2	30.1	32.8	31.7	28.2	25.5	27.8	81.5	1.27	1.14	1.205	4.82	3.85	8.67	8.083	30.0	13400	805000	19310000	29.3	27.3	.933	.472	Generator thrown in.
.36			66	143	77	70	240	58.8	—	292	216	146	32.0	27.8	32.5	30.8	27.2	22.9	26.7	76.8	1.24	1.14	1.190	4.82	3.85	8.67	8.083	30.0	13400	805000	19310000	29.3	27.3	.933	.502	
.44			65	157	92	69	220	58.8	48	288	213	144	31.8	23.8	29.6	28.4	26.7	19.1	24.0	69.8	1.15	1.02	1.085	4.76	3.62	8.38	8.083	28.3	12680	760000	18250000	27.7	25.9	.933	.323	
.52			64	152	88	69	218	58.8	—	280	207	140	27.3	26.1	29.8	27.7	22.3	20.4	23.5	66.2	1.10	1.10	1.100	4.52	3.74	8.26	8.083	30.5	13190	791000	19000000	27.5	26.9	.980	.548	
7.00	50		64	146	82	71	224	58.8	—	280	207	140	31.4	24.5	(14.7)	23.5	25.6	19.3	11.37	56.3	.93	.96	.945	4.31	3.74	8.05	8.083	27.5	12250	735000	17670000	25.0	25.0	1.000	.585	
.08			64	146	82	76	224	58.8	—	276	204	138	31.2	23.9	29.0	28.0	25.1	18.4	22.5	65.0	1.02	.895	.9575	4.31	3.85	8.16	8.083	26.5	11870	713000	17100000	24.5	24.2	.990	.498	
.16			64	145.5	81.5	78	220	58.8	—	250	185	125	23.8	27.9	30.5	27.4	17.4	16.0	21.5	54.9	.99	.855	.9225	3.97	3.52	7.49	8.083	27.6	11600	696000	16700000	21.9	23.7	1.080	.527	
.24			64	138	74	76	220	58.8	—	260	193	130									.86	.67	.765	3.40	3.63	7.03	8.083	23.9	10250	615000	14750000	18.2	20.9	1.145		
.32			62	137	75	70	216	58.8	—	264	196	132									.96	.79	.875	3.63	3.51	7.14	8.083	24.9	11150	670000	16090000	20.1	23.5	1.170		
.39			63	140	77	80	220	58.8	—	280	207	140	32.8	28.5	30.4	30.6	26.8	22.4	24.0	73.2	.96	.876	.918	4.31	3.63	7.94	8.083	26.3	11710	705000	16900000	23.5	23.9	1.015	.423	
.47			63	149	86	76	224	58.8	—	286	212	143	31.7	30.2	31.3	31.1	26.5	24.3	25.2	76.0	.97	.92	.945	4.53	3.74	8.27	8.083	26.9	12000	720000	17300000	25.0	24.5	.980	.434	
.55			63	156	93	74	220	58.8	—	280	207	140	29.6	24.5	28.0	27.3	24.2	19.2	22.0	65.4	.970	.92	.945	4.41	3.51	7.92	8.083	26.9	12000	720000	17300000	24.0	24.5	1.020	.416	
8.03		69.5	63	158.5	95.5	78	238	58.8	—	284	210	142		33.0	29.8			26.3	24.2		.9875	.92	.9475	4.30	3.63	7.93	8.083	26.9	12000	720000	17300000	24.1	24.6	1.015		Fires cleaned
.10			63	166	103	77	244	58.8	—	285	211	142.5		28.5	32.0			24.0	24.0		1.000	.98	.990	4.53	3.51	8.04	8.083	27.8	12400	745000	17850000	25.1	25.3	1.010		
.18			62.5	176	113.5	73	256	58.8	—	280	207	140		27.7	31.3			21.8	24.8		1.015	.96	.9875	4.53	3.51	8.04	8.083	27.5	12250	735000	17670000	24.8	25.0	1.010		
.26			62	181	119	71	232	58.8	—	288	213	144		31.8	31.5			25.8	25.7		.096	.875	.9175	4.42	3.51	7.93	8.083	26.1	11710	705000	16900000	23.5	23.9	1.020		
.34			56	145	89	66	244	58.8	—	294	218	147		35.0	36.3			29.2	30.2		1.04	.96	1.000	4.10	3.74	7.84	8.083	27.5	12250	735000	17670000	24.3	25.0	1.030		
8.42			62	195	133	66	315	58.8	—	295	219	147.5		32.6	34.2			27.2	28.5		1.06	.96	1.010	5.10	3.51	8.61	8.083	27.5	12250	735000	17670000	26.7	25.0	.936		
9.50			—	—	—	—	—	58.8	—	288	213	144		36.7	29.3			21.2	23.8		1.26	.71	.985	4.76	3.63	8.39	8.083	24.9	11150	670000	16090000	23.5	23.8	.970		Jack Shaft Run by Auxiliary Engine.
9.55			—	—	—	—	—	58.5	—	288	213	144	32.6	30.7	27.5	30.3	27.4	25.0	22.2	74.6	1.26	.67	.965	4.76	3.74	8.50	8.083	22.9	10250	615000	14750000	22.0	20.9	.950	.389	
10.00			63	95	32	—	—	58.5	—	290	215	145	31.2	30.1	34.0	31.8	26.4	24.6	27.9	78.9	1.26	.79	1.026	4.76	3.63	8.39	8.083	24.9	11150	670000	16090000	23.6	22.8	.970	.393	
.05			63	112	49	—	—	58.5	—	288	213	144	29.6	27.7	33.6	30.2	24.9	22.5	27.1	74.5	1.04	.915	.9775	4.65	3.74	8.39	8.083	26.9	12000	720000	17300000	25.3	24.5	.970	.447	
.10			—	—	—	—	—	58.5	—	290	215	145	34.7	27.2	36.8	32.9	29.4	12.2	30.3	71.9	1.21	1.02	.615	4.65	3.74	8.39	8.083	28.3	12680	760000	18250000	26.7	25.9	.970	.489	
10.15			—	—	—	—	—	58.5	—	288	213	144	33.0	22.1	30.4	28.5	27.7	17.8	24.7	70.2	1.15	1.08	1.115	4.65	3.74	8.39	8.083	29.2	13500	810000	18800000	28.5	27.6	.970	.534	
TOTAL	511.5	421.5	3084.5	6776.3	3721.5	3328	11713	3085.7	1244.8	15360	11390	7680	1348.2	1338.7	1407.1	1153.7	1131.5	1071.3	1129.17	2848.6	51.095	47.951	47.9465	242.34	173.21	438.03		1419.28	634.950	38013000	914072000	1359.2	1351.3	49.144	18.020	
AVGE.	65.2	70.1	64.3	141.8	77.5	72.3	254.6	59.4	59.3	295.0	219.0	147.5	32.1	27.3	30.6	29.6	27.0	21.9	24.1	73.0	.984	.940	.962	4.66	3.77	8.43	8.083	26.6	12450	746000	17910000	26.61	26.5	.945	.475	
																						.94	.962													

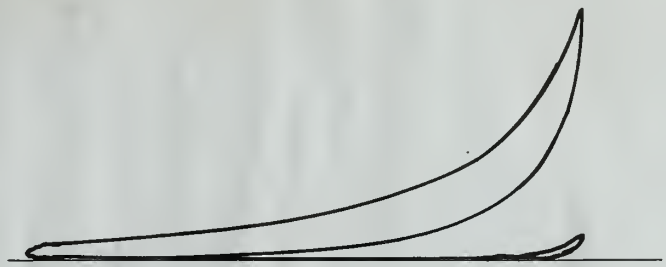
OBJECT of TEST— Mechanical Efficiency of Engine
BAROMETER— 28.35
WEATHER CONDITIONS— Fair.

		MECH EFF.	REMARKS
23	TOTAL 20	21	
31.4	93.0	84.6	
34.7	99.0	96.0	
29.0	94.3	97.5	
35.0	114.8	77.5	
			5 PM Spark advanced to 180°.
24.2			
28.0	90.5	47.0	
17.0	86.7	49.5	
25.0	80.5	79.5	
33.9	93.6	78.0	
34.5	93.2	79.5	
40.4	114.0	83.3	
35.0	103.0	92.1	
343.9	1061.6	864.5	
31.2	96.6	78.6	

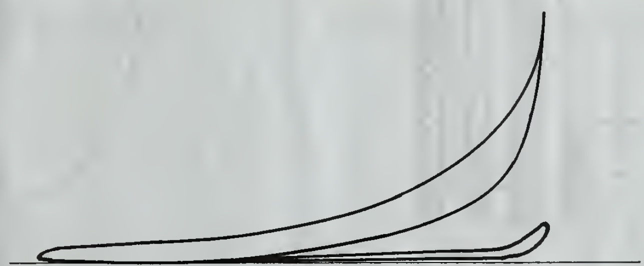
2 1
4.37 5.40 P.M.
1 hr., 3 min.

Mechanical Efficiency of Engine
28.35
WEATHER CONDITIONS Fair.

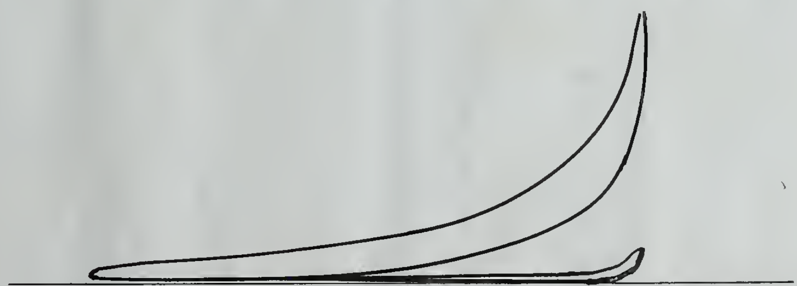
P.M.	Temperatures: Air		Jacket Water		Diff.	Gas	Exhaust	8	R.P.M.	Eff. R.P.M.	Wt. on Scales	B.H.P.	I.E. No. 1		No. 3					Total		REMARKS
4.37			58	138	80		234		256	128	525	78.6	46.6	36.3	42.5	41.8	34.6	27.0	31.4	93.0	84.6	
:40			58	137	79		231		308?	154	525	95.0	41.3	33.7	38.7	37.9	41.7	22.6	34.7	99.0	96.0	
:44			58	137	79		234		280	140	560	92.0	42.7	37.0	35.6	38.4	35.0	30.3	29.0	94.3	97.5	
:49			57	136	79		231		316	158	480	89.0	46.8	39.6	38.1	41.5	43.3	36.5	35.0	114.8	77.5	
:50									340	170	(75)	(15.)										5.00 PM Spark advanced to 180°.
5:10			60	115	55				316	158	205	38.0			25.7				24.2			
:20			60.5	120	59.5				310	155	235	42.6	36.8	32.3	29.9	33.0	33.3	29.2	28.0	90.5	47.0	
:24									316	158	225	41.8	35.6	41.0	18.6	31.7	32.8	37.8	17.0	86.7	49.5	
:28			60	110	50				256	128	425	64.0	40.0	34.7	33.5	36.1	29.7	25.8	25.0	80.5	79.5	
:30			60	110	50				290	145	430	73.0	41.7	29.9	40.0	37.2	34.4	25.3	33.9	93.6	78.0	
:33			59.5	110	50.5				288	144	440	74.2	41.8	29.0	41.1	37.3	34.4	24.3	34.5	93.2	79.5	
:37			60	122	62.0				292	146	555	95.0	49.3	37.3	47.4	44.6	41.9	31.7	40.4	114.0	83.3	
5:40			59.5	144	84.5				274	137	590	95.0	47.9	37.1	43.6	42.6	38.3	29.7	35.0	103.0	92.1	
Total			650.5	1379	728.5		930		3842	1921	5195	878.2	470.5	387.9	409.7	422.1	399.4	320.2	343.9	1061.6	864.5	
Avge.			59.1	125.3	66.2		232.5		296	148	432.9	73.2	42.8	35.2	37.2	38.4	36.3	29.1	31.2	96.6	78.6	



Cylinder No. 1



Cylinder No. 2

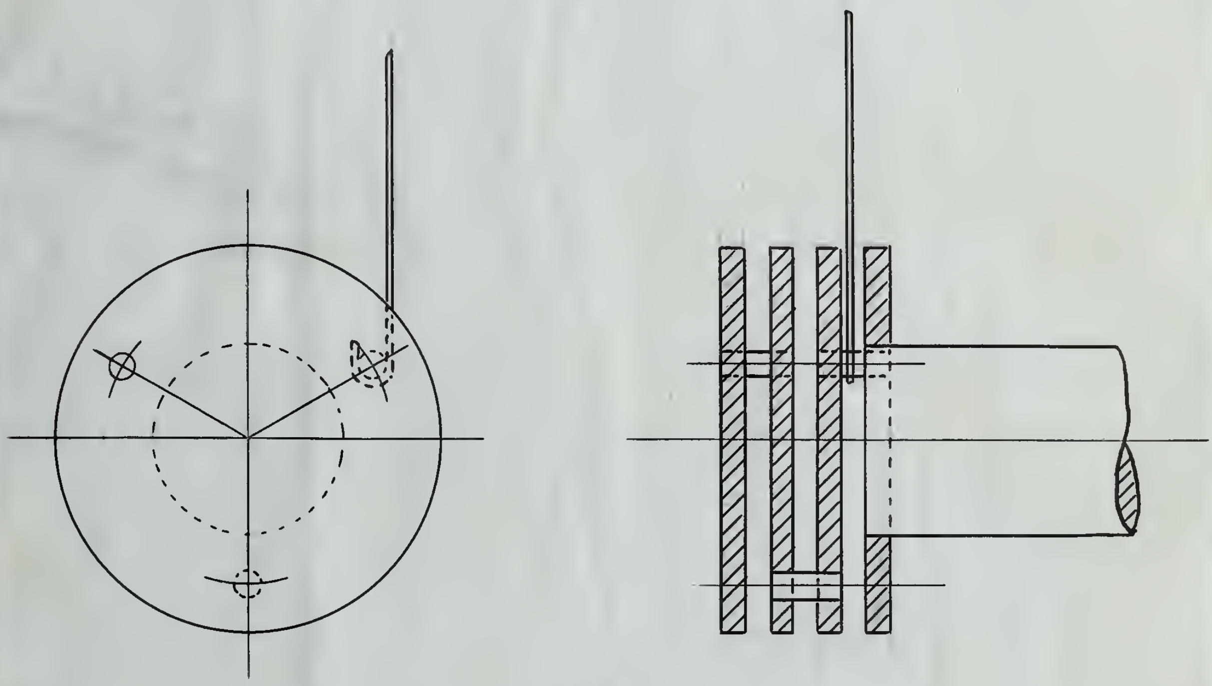


Cylinder No.3

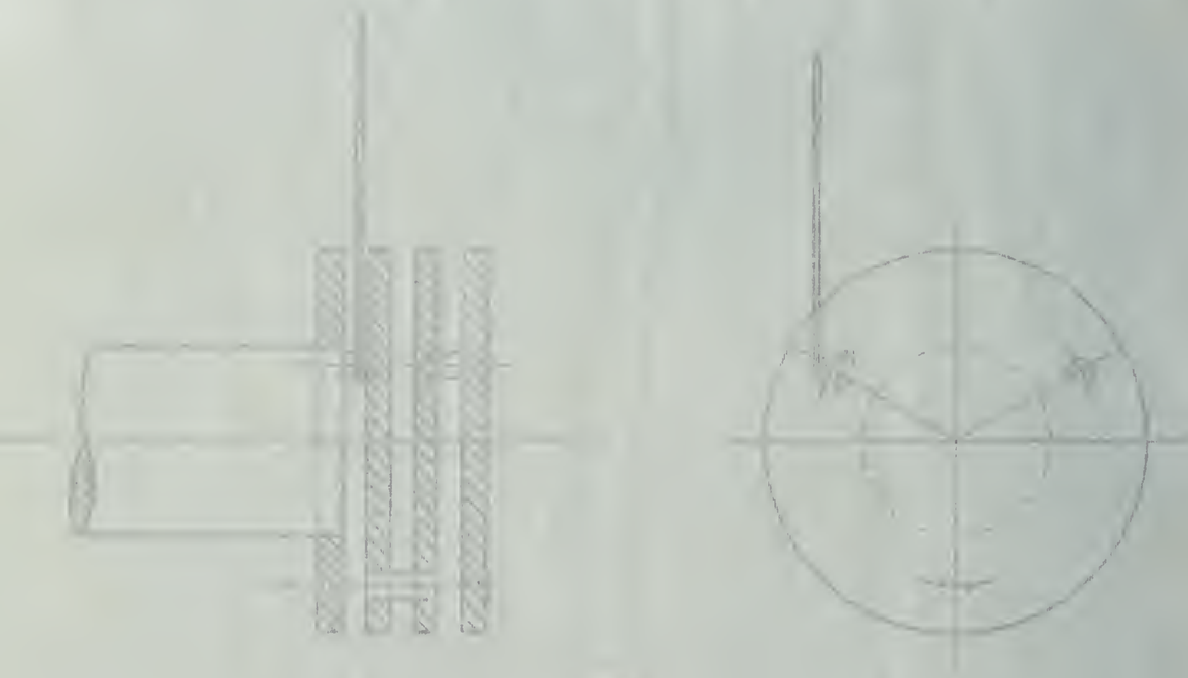
Indicator Diagrams No. 33

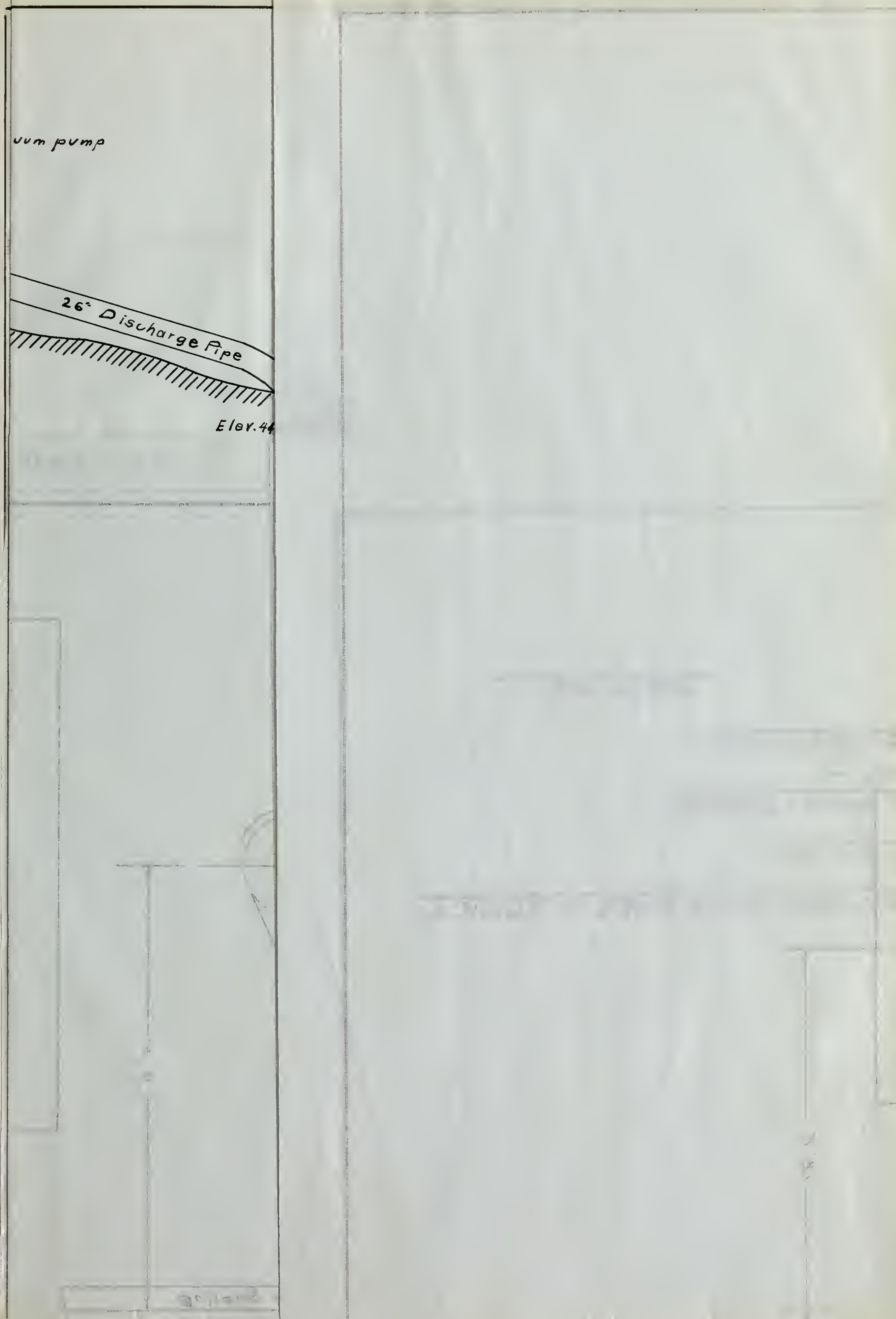
Test No.1, Trial No.2

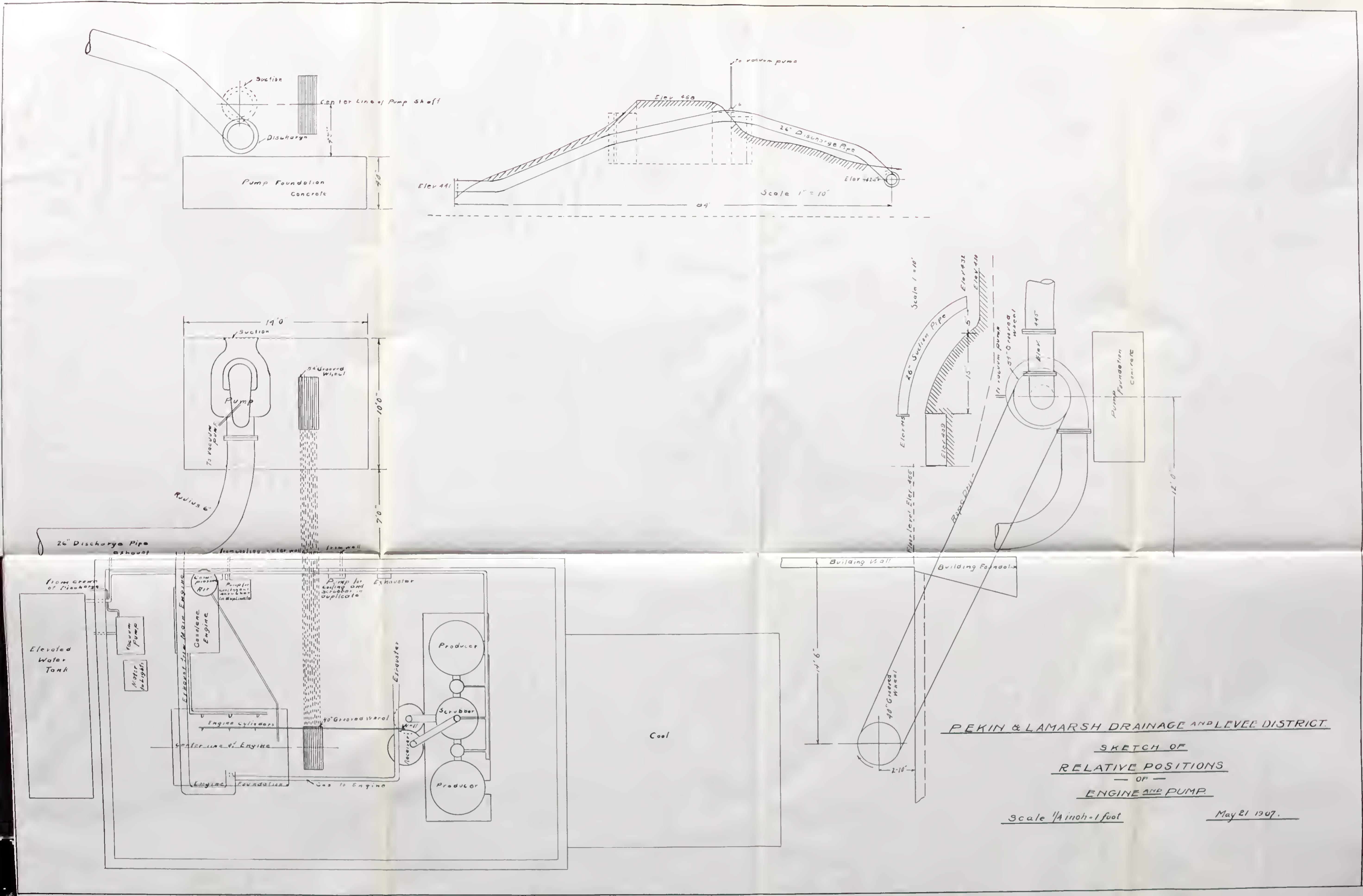
March 26, 1908 Pekin, Ill.



REDUCING MOTION




uum pump
26" Discharge Pipe
Elev.44



PEKIN & LAMARSH DRAINAGE AND LEVEE DISTRICT
SKETCH OF
RELATIVE POSITIONS
— OF —
ENGINE AND PUMP
Scale 1/4 inch = 1 foot
May 21 1907.
Suction
Center Line of Pump Shaft
Discharge
Pump Foundation
Concrete
To vacuum pump
Elev 458
26" Discharge Pipe
Elev 441
Scale 1" = 10'
84'
Suction
Pump
54" Grooved Wheel
To vacuum pump
Radius 6'
26" Discharge Pipe
14'0"
10'0"
7'0"
Exhaust
From cooling water well
From well
From crown of Discharge
Compressor
Pump for cooling and scrubber in duplicate
Exhauster
Elevated Water Tank
Vacuum Pump
Gasolene Engine
Motor for lights
Exhaust from Main Engine
Producer
Scrubber
Receiver
40" Grooved Wheel
Engine cylinders
Center line of Engine
Engine Foundation
Gas to Engine
Producer
Coal
Scale 1" = 10'
26" Suction Pipe
Pump Foundation Concrete
Water level Elev 435
Building Wall
Building Foundation
Rope Drive
40" Grooved Wheel
12'0"
14'6"
2-10"